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Nr. 6. Johs. Schmidt: MARKING EXPERIMENTS ON PLAICE AND COD IN ICELANDIC WATERS. WITH 2 CHARTS

Nr. 7. Johs. Schmidt: ON THE POST-LARVAL DEVELOPMENT OF THE HAKE (*MERLUCCIUS VULGARIS* FLEM.). WITH ONE PLATE AND 4 FIGURES IN THE TEXT

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1907

MEDDELELSER FRA KOMMISSIONEN FOR HAVUNDERSØGELSER
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MARKING EXPERIMENTS ON PLAICE AND COD IN ICELANDIC WATERS

BY

JOHS. SCHMIDT

WITH 2 CHARTS

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
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I. INTRODUCTION

THE marking experiments which form the subject of the present report were carried out at Iceland by the author from the "Thor" in the summer months of 1903, 1904 and 1905. The experiments fall into two divisions, as partly plaice (*Pleuronectes platessa*) and partly cod (*Gadus callarias*) were marked.

1. Marking experiments on plaice

These were made, partly in the summer of 1903 when 280 plaice were marked and set free in Skiálfandi Bay in North Iceland, partly in the summer of 1905 in Vopna Fjord on the northern portion of the east coast where 494 plaice were marked and set free. The chief objects of these plaice marking experiments were, firstly, to obtain in this way material for the comparison of regions, where there are many plaice but where the fishery is carried on to a comparatively small extent, with other waters, e. g. the North Sea, where as is well-known the plaice fishery is carried on with the greatest intensity. For this reason, the north and east coasts of Iceland, where there is but little fishing for plaice in comparison with the south and west of Iceland, were chosen for the experiments. Other main objects with these marking experiments were, to obtain information regarding the growth of the plaice and its migrations in these northern waters so characteristic in hydrographical regards.

2. Marking experiments on cod

These were begun in the summer of 1904 on the east of Iceland, where cod were marked and set free in Loðmundar Fjord and in Héraðs Bay. They were continued in the summer of 1905 on the north of Iceland, cod being marked and set free at Málmey in Skaga Fjord and a smaller number in Eyja Fjord and Siglu Fjord.

The experiments were chiefly made on cod not quite full-grown, the majority measuring between 40 and 60 cm. (the sizes called by the Iceland fishermen "þyrsklingar" and "stútungar"). The object of these experiments was, firstly and principally, to determine whether, these sizes of the cod, which are so exceedingly common on the north and east coasts in summer and autumn, also pass the winter and early spring on these coasts, where the water at those seasons is of very low temperature. To obtain information on this matter is indeed of great importance, even in practical regards. My earlier investigations at Iceland with the "Thor" had shown, that the full-grown cod, which are very large there (about 80—90 cm.), collect together in the spring in the warmer Atlantic waters on the south and south-west coasts in order to spawn, and that the reproduction mainly takes place there and not or

JOHS. SCHMIDT: Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 (Skrifter udgivne af Kommissionen for Havundersøgelser No. 1, 1904, 8vo).

to a much less extent on the north and east coasts (see text figure p. 20). As mentioned, the water on the last-named coasts is of low temperature, especially in spring and winter, when no adult, spawning cod are to be found there. On the other hand, great shoals of spent cod occur there in summer and autumn and the cod fishery is thus carried on mainly during those seasons. As the adult fish then migrate to the south and south-west coasts in order to spawn, it might be thought, that the somewhat younger years' groups also left the cold water of the east and north coasts in winter and like the adults collected together in the warm Atlantic water. To get this point cleared up was, as mentioned, the main object of the marking experiments. There were naturally other objects also, e. g. to obtain information on the growth of the cod at Iceland and on the extent of whatever migrations it might make.

3. Methods of marking in the Icelandic experiments

The plaice were marked according to the method first introduced by Dr. C. G. Joh. Petersen; two bone buttons connected by silver wire, the one branded with a No and "Da" (Denmark), are fastened to the fish close below the dorsal fin. In addition to the bone buttons a small brass disc was usually fastened to the silver wire, bearing the same number as that on the bone button, in case the latter should become unreadable.

There is nothing else to remark with regard to the plaice marking, which was carried out on fish taken with a small 50-foot otter-trawl of the "Thor".

With regard to the marking of the cod, I first endeavoured to use some small, thin rods of silver hammered out at the ends to small plates on which the number was stamped. These silver rods, which were inserted into the gill-cover of the cod and then bent, had been used for marking cod in the inner Danish waters. It soon appeared however, that they were unsuitable for Iceland, as they were but little evident on the large Iceland cod and were therefore not observed by the Icelandic fishermen, who moreover as a rule cut the head off the fish immediately on hauling it up on their lines.

I then made several attempts at marking the cod with the same marks (bone buttons connected by a silver wire) as were used for the plaice, and found them very successful, as the large, white buttons were very easily observed by the fishermen. The marks were fastened about the centre of the gill-cover between the opercular bones (see Figure p. 6), and the method of marking was to lift up the gill-cover with the right hand, pass the silver wire with the one bone-button on it into the gill-opening with the left hand and push it through the gill-cover outwards; the second button was then inserted on the wire and the latter bent over. The first experiments with the method were made in July 1904 in the small fjord Loðmundar Fjord[1] on the east coast, just north of Seyðis Fjord. The fjord was then full of the young of the lodde (*Mallotus villosus*) and it was likewise swarming with cod, which were gorging themselves on this their favourite food, so that it was very easy to procure material for the marking experiments. The "Thor", which had been fitted out in Seyðis Fjord with a large welled box, anchored in the evening at a sheltered spot in the fjord over ca. 12—14 fathoms water, and lines with small hooks baited with herring were then set out with the aid of the ship's boats. The hooks were lifted early in the morning by a large, welled smack and the cod immediately after being taken from the hooks were placed in the well. They were then brought over into the large welled box, where they remained for a day so that the fish damaged on capture might be sorted out. On marking, the cod were taken out of the box by means of a bucket and immediately after being measured and marked, thrown into the sea. We also made the experiment of placing some of the marked cod back into the box and left them there for some time, to see if they had in any way been damaged by the marking. This seemed not to be the case in

[1] For the result of one of these fishing experiments with hooks in Loðmundar Fjord, see Johs. Schmidt: Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 (l. c. p. 29).

the least, all the cod were lively when taken from the box and were then put into the sea. As will be seen later, not a few of the cod marked in Loðmundar Fjord were recaptured and it seems therefore, as if the method of marking described was very practicable, at any rate when the cod are not too small, like the Iceland cod. If small cod (e. g. 20—30 cm.) are to be measured, small marks should be used, as the bones of the size used here will probably take up too much room in the gill-cavity and thus easily damage the gills or impair their function.

In the same manner as that just described cod were several times marked at Iceland later, in 1904 and 1905, once however (in Héraðs Bay) with the difference, that the fish had been trawled.

As is well-known, fishermen of many different nations fish at Iceland, amongst them also some of other nations than those taking part in the international investigations. It was to be expected therefore, that some of the marked fish would fall into the hands of other fishermen, as well as those acquainted in the North Sea, Skager Rak and Kattegat fisheries with what they should do in regard to forwarding marks and information of the marked fish. For this reason special preparations had to be made to make it possible that all the fishermen engaged in fishing round Iceland should know of the marking experiments, as the results obtained from these might otherwise be seriously depreciated in value.

In addition to the Icelanders themselves, the boats fishing at Iceland are chiefly British, but also German, Dutch, Belgian, Norwegian, French and Færoese. Of these, the British, German, Dutch, Belgian and Norwegian could be considered as knowing about marking experiments from the advertisements in their own country and from fishing in the North Sea. There remained the Icelanders, the French and the Færoese, all three taking yearly a very considerable proportion of the fish, especially cod, caught at Iceland.

With regard to the Icelandic fishermen, the zoologist, cand. mag. BJARNI SÆMUNDSSON of Reykjavik, who had taken part in the "Thor's" Iceland cruises in each of the three years, kindly undertook to receive the marks from the fishermen and pay them the reward. I then inserted a notice on the matter in some Icelandic papers on the east and north coasts, and Mr. SÆMUNDSSON did the same as regards the south and west coasts and he likewise drew up the notice below[1] to the Icelandic fishermen, which was printed and distributed over the whole island and fixed up in the shops the fishermen dealt with.

With regard to the Færoese fishermen, a large number of notices with similar contents to the French one given on p. 6 were printed and sent to shipowner JENS ANDREASEN of Thorshavn in the Færoes who kindly undertook to distribute the notices among the cutters sailing to Iceland from the Norder Islands, whilst specimens were sent directly to the Færoese owners at Suderø.

Mr. ANDREASEN as well as Mr. OLAF FINSEN, chemist at Thorshavn, kindly undertook to receive the marks at the Færoes and the latter published a note concerning them in a Thorshavn paper.

It was more difficult for me to come to some arrangement with the French fishing at Iceland, so that it was with great pleasure that I received a friendly offer from M. CH. RABOT of Paris, my correspondent for many years, to act as intermediary between the French fishermen and the fisheries investigations at Iceland, and to receive the marks from the French fishermen. The accompanying notice (p. 6), which was translated by M. RABOT, was then sent, according to the list published yearly of all the French

[1]

Fiskimenn!

Munið eftir, ef þér fáið merkta þorska,

1.) að hirða merkið, og

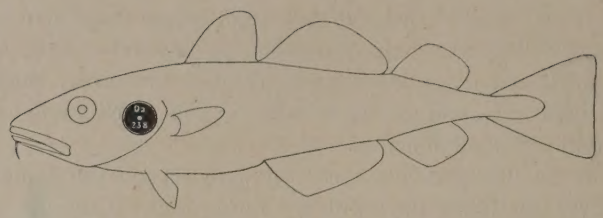
2.) að senda það til BJARNA SÆMUNDSSONAR i Reykjavík, ásamt stuttri skýrslu um, hvaða dag og hvar fiskurinn var fenginn og hve langur hann var með höfði og hala. Þér fáið svo 1 krónu fyrir hvert merki.

Fishermen!

If you should catch any marked cod, remember

(1) to remove the mark and

(2) send it to BJARNI SÆMUNDSSON in Reykjavik, along with a short note on the date and place where the fish was caught and how long it was from head to end of tail 1 krone is obtained for each such mark.



Aux pêcheurs d'Islande.

En vue d'étudier les migrations et la croissance de la morue dans l'intérêt des pêcheurs de tous les pays, la mission officielle danoise des Pêcheries embarquée sur le vapeur „Thor" a attaché des boutons en os et en laiton à un grand nombre de morues qui ont été ensuite rejetées à la mer sur divers points au large de l'Islande. Comme le montre la figure ci-dessus ces boutons sont numérotés, munis des lettres „Da" (Danemark) et attachés aux opercules des morues.

Les pêcheurs français qui capturéraient des poissons ainsi marqués sont instamment priés de conserver soigneusement ces boutons, de remplir le questionnaire ci-joint et de remettre boutons et formulaires remplis à l'armateur de leur navire qui sera prié de faire parvenir ces pièces à M. Charles Rabot, Secretaire adjoint de la Société de Géographie de Paris, 184 Boulevard Saint Germain. Paris VI.

M. Charles Rabot transmettra ensuite boutons et questionnaires à la Commission danoise des Pêcheries à Copenhague. Pour chaque bouton accompagné d'un questionnaire dûment et completement rempli, le pêcheur recevra de la mission danoise la somme d'une couronne, soit 1 f. 40 centimes. Par les soins de M. Charles Rabot la somme de 1 f. 40 sera expediée par mandat carte dès la reception des boutons et des questionnaires dûment et completement remplis. La lettre contenant le questionnaire et les boutons devra être recommandée. Le montant des frais de poste sera acquitté dès la reception par les soins de M. Charles Rabot à l'armateur qui en aura fait l'avance.

Copenhague, Janvier 1905.

---

1) En quel point la morue marquée a-t-elle été péchée? .....

.....

2) A quelle date? ..... *3) A quelle profondeur?* .....

4) Quelle était la longueur de la morue de l'extrémité du museau à celle de la queue? .....

5) Quel était le numéro des boutons attachés au poisson? .....

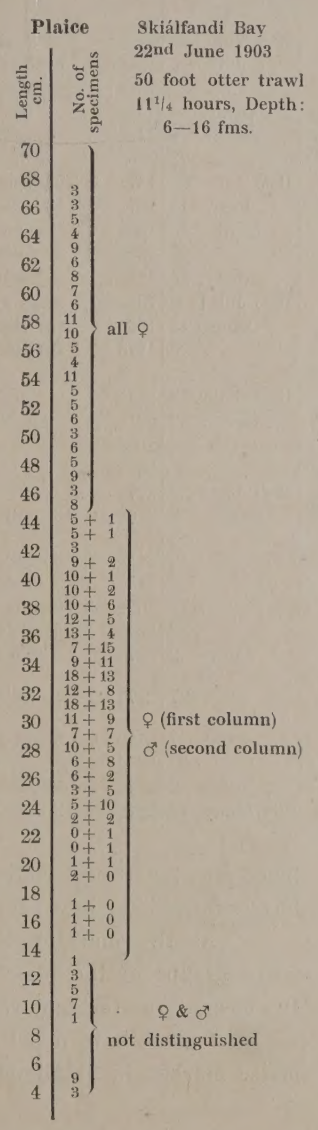
Nom et adresse du pêcheur qui a droit à la prime: .....

.....

Signature du capitaine: ..... *Signature de l'armateur:* .....

boats taking part in the Iceland fishery, to all the French companies concerned (in Dunkirk, Gravelines, Paimpol, Boulogne etc.) with the request that they should give copies to their boats. So far as I have been able to judge from enquiries at Iceland, most of the French boats really had copies of the notice in their possession, so that the conditions were apparently favourable for the receipt of marks from the French side.

I would use this occasion to tender M. RABOT my most sincere thanks for the ready willingness with which he undertook this trouble, and thus as so often showed his interest in the Danish scientific investigations.



II. MARKING EXPERIMENTS ON THE PLAICE *(PLEURONECTES PLATESSA)*

These fall into two groups (A) and (B). The first are

(A) Experiments in Skiálfandi Bay (north coast)

These experiments were carried out on June 27th and July 1st, 1903 in Skiálfandi Bay on the north coast (about 66°00′ N., 17°29′ W.).

Like the other easterly bays on the north coast Skiálfandi Bay is an open bay in which there are many places with sandy bottom, well suited to the plaice. There is but little traffic in this bay with but one business centre and that not very large called Husavík. The inhabitants are but little interested in the plaice fishing, and the only fishery for plaice of any importance there is carried on by the English trawlers, a few making an occasional journey here in the summer when plaice are scarce on the south and west coasts. Altogether however, the English fish but little for plaice in Skiálfandi Bay, where the fishing grounds further are within Icelandic territory, and the stock of plaice is thus relatively intact, which could be clearly seen from the hauls made there by the "Thor". These gave comparatively many very large plaice, as can be seen from the accompanying single example. It is clear that the conditions there are quite different from those prevailing in greatly fished waters such as the North Sea and Kattegat, where such large plaice as are common in Skiálfandi Bay are almost entirely fished out.

The greater part of the stock of plaice in Skiálfandi Bay is apparently not born on the spot. Thus, the young of the year were sought for in June both in 1903 and 1904, but without result, whereas they were found (pelagically) in quantities in the same month off the north-west coast. It was only later in the summer that they occurred in Skiálfandi Bay, as was shown by the 1904 investigations. Thus, at the end of July and in August 1904 we found the just transformed plaice in quantities in Skiálfandi Bay, where we had sought for them in vain earlier in the year, and it further appeared that it is still later in the year before they are met with in the fjords of the east coast. There is thus scarcely any doubt that the warm current (Irminger Current), which is moving eastward in the summer off the north coast, is of impor-

Particulars of Liberation. Date. Locality. No. of Fish. etc.	Particulars of Recovery									
	Date	No. on Label	Sex	Locality reported	Central Position (Approximately) N W	Fishing Vessel	No of months between Liberation and Recovery	Initial Size cm.	Ultimate Size cm.	Sent in by
A. 1903 June 27 and July 1 280 plaice No. 1221—1500 Skiálfandi Bay 66°00′N 17°29′W	1904 June 18	1344	♀	Akreyrihöfn, Eyja Fjord, Iceland	65°40′ 18°02′	Icel.fish.boat	12	48·5	51·5	Friðrik Kristjansson, Akureyri
	» July 5	1256	♀	Svalbardseyri, North- —	65°45′ 18°03′	» »	12	48	?	Bjarni Sæmundsson, Reykjavik
	» » 22	1318	♀	Húsavík, Skiálfandi Bay, — — 23 fms.	66°03′ 17°21′	» »	13	38	41·5	— —
	» August 16	1358	♀	Iceland	?	English S. S.	13	46	48·9	Marine Biol. Assoc., Lowestoft
	» Septbr. 10	1464	♂	14 m. off Isafjarðardjúp, NW- — 65 fms.	66°33′ 23°39′	» »	14	37	41·3	— —
	» » 23	1263	♀	Iceland	?	» »	14	40	44·5	— —
	1905 July 26	1377	♀	2 miles NW of Gjögr, North- — 60 fms.	66°12′ 18°18′	Icel.fish.boat	25	30	?	Bjarni Sæmundsson, Reykjavik
	» Febr. 15	1271	♀	13 miles off Dýra Fjord, NW- — 35 fms.	66°00′ 24°47′	English S. S.	19	36	42·5	Marine Biol. Assoc., Lowestoft
	» Septbr. 23	1369	♀	Húna Bay, North- — 40 fms.	65°52′ 20°40′	» »	26	31	40·2	— —
	» » 28	1322	♂	22 miles off Isafjarðardjúp — 55 fms.	66°37′ 23°28′	» »	26	35	41	— —
	» Novbr. 25	1281	♀	Iceland	?	» »	28	46		— —
	1906 July 6	1319	♀	Axar Fjord, North- — ?	66°22′ 16°48′	» »	36	33	41·2	— —
	» October 13	1364	♂	Off Isafjarðardjúp, NW- — 41 fms.	66°29′ 23°22′	» »	39	32		— —
	» » 30	1273	♀	Off Isafjarðardjúp, — — 36 fms.	66°29′ 23°15′	» »	40	33·5	44	— —
B. 1905 July 28 and 29 494 plaice No. 2001—2494 Vopna Fjord 65°45 N 14°45′W	1905 Octbr. 29	2245	♀	Iceland	?	English S. S.	3	57		Marine Biol. Assoc., Lowestoft
	» Novbr. 30	2218	♂	6 mil. NW of Kollumúli, East-Icel. 50 fms.	65°51′ 14°30′	» »	4	33·5	36·2	— —
	» » »	2004	♀	— — — —	— —	» »	4	35·5	37·3	— —
	» » »	2069	♀	— — — —	— —	» »	4	33	35·8	— —
	1906 Jan. 28	2470	♀	12 m. ESE of Portland, South- — 56 fms.	63°21′ 18°40′	» »	6	45	46·7	— —
	« April 8	2168	♀	31 miles SW by W of Ingólfshöfði — 66 fms.	63°30′ 17°35′	» »	8	43	44·7	— —
	» » 18	2412	♂	35 miles SW of Ingólfshöfði — 65 fms.	63°30′ 17°40′	German S. S.	9	38	40	Kgl. Biol. Anstalt auf Helgoland
	» » 18	2455	♂	3 miles E of Ingólfshöfði — 25 fms.	63°50′ 16°30′	» »	9	37	38	— —
	» » 16	2054	♂	5 miles SE of Ingólfshöfði — 60 fms.	63°44′ 16°43′	» »	9	41	42	— —
	» » 22	2266	♂	5 miles SE of Ingólfshöfði — 67 fms.	63°45′ 16°45′	» »	9	35	37	— —
	» May 9	2270	♂	5 miles E of Bjarnarey (Vestmannaeyjar) — 54 fms.	63°27′ 20°00′	English S. S.	9	37	39·7	Marine Biol. Assoc., Lowestoft
	» » 27	2174	♀	15 miles SE by E of Ingólfshöfði — 56 fms.	63°40′ 16°10′	German S. S.	10	56	58	Prof. D'Arcy Thompson, Dundee
	» June 7	2150	♀	3 miles SE of Ingólfshöfði — 33 fms.	63°46′ 16°42′	» »	10	33	35	Kgl. Biol. Anstalt auf Helgoland
	» » 20	2254	♀	Iceland	?	English S. S.	11	36	?	Marine Biol. Assoc., Lowestoft
	» July 12	2023	♀	Vopna Fjord, East- — 15 fms.	63°43′ 14°45′	Icel fish.boat	12	31	?	Bjarni Sæmundsson, Reykjavik
	(1907[1] March 13	2222	♀	2 miles off Ingólfshöfði, S.- — ?	63°50′ 16°29′	German S. S.	20	43	46	Kgl. Biol. Anstalt auf Helgoland)

tance for the transportation of the plaice young to the north and east coasts, just as our investigations have shown it to be so for the young of the cod and other fishes.

As the marking experiments were made late in June 1903, Skiálfandi was thus rich in all years' groups of the plaice with exception of the 0-group. The size of the marked plaice varied from 19–69 cm., but the majority were between 30 and 50 cm.

I give above a list constructed on the usual plan of the particulars regarding the recovery of the plaice marked in Skiálfandi Bay. Further information is given in Chart I.

B. Experiments in Vopna Fjord (east coast)

These experiments were carried out in July 1905 in Vopna Fjord on the northern part of the east coast. What has been said above concerning the stock of plaice and the plaice fishery in Skiálfandi Bay holds good in the main for this fjord also. But the English trawlers fish somewhat more here than in

[1] This fish was received after the text and charts were printed.

Skiálfandi Bay, so that the stock is not so undisturbed as there. The size of the plaice marked varied from 23 to 69 cm., but the majority were between 30 and 50 cm.

The particulars of the recoveries can be seen from the list above and from Chart I.

I may now give the conclusions to be drawn from the marking experiments on plaice at Iceland.

Rate of growth

The Skiálfandi Bay experiments on the north coast are best suited to show the growth, as all the fish in question had been a long time in the sea before recovery, some even unusually long, quite three years and more. The details can be best seen from the following summary.

Plaice marking experiments A

280 plaice marked, 27/VI and 1/VII, 1903, in Skiálfandi Bay in North Iceland (ca. 66° 00′ N, 17° 29′ W)

Year and Month recovered	Period of growth (months)	No. of specimens	Average growth in cm.	Least growth in cm.	Greatest growth in cm.	Retaken

To be inserted p. 8 in Meddelelser fra Kommissionen for Havundersøgelser, Serie: Fiskeri Bind II. Nr. 6. 1907.

Marking Experiment B (July 1905, Vopna Fjord).

(Particulars of Recovery of Plaice received after the paper was printed.)

Date	No. on Label	Sex	Locality reported	Central Position (Approximately) N. W.	Fishing Vessel	No. of months between Liberation and Recovery	Initial size cm.	Ultimate size cm.	Sent in by
1907, April 1	2344	♀	Off Skagi Light	64°07′ 22°39′	English S.S.	20	46		Marine Biol. Assoc., Lowestoft.
1907, May 15	2226	♂	Off Ingólfshöfði	63°47′ 16°28′	German S.S.	22	35	39·2	Professor D'Arcy W. Thompson, Dundee.
1907, May 16	2413	♀	12 miles S.S E. 3/4 E. of Ingólfshöfði, 45 fathoms	63°43′ 16°15′	English S.S.	22	44	51·2	Marine Biol. Assoc., Lowestoft.
1907, June 24	2042	♀	Off Lánganes	66°27′ 14°11′	English S.S.	23	34	39·6	»

following Table B.

[1] The average shrinkage of the fish from the time of capture until measured is taken to be 1/2 cm.

[2] A. C. Johansen: Ueber die Schollenfischerei im Kattegat und die Mittel sie zu heben (Extrait du Rapport de la Commission C_2, vol. V, des Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, 1906, p. 109—111.

Plaice marking experiments B

494 plaice marked 28—29th July. 1905 in Vopna Fjord in NE Iceland (ca. 65°45′ N, 14°45′ W)

Year and month of recapture	Period of growth (months)	No. of Specimens	Average growth in cm.	Least increase in cm.	Greatest increase in cm.	Recaptured
1905, November	4	3	2·9	2·3	3·2	East Iceland
1906, January	6	1	2·2	2·2	2·2	South Iceland
1906, April	8	1	2·2	2·2	2·2	
1906, April & May	9	5	2·1	1·5	3·2	
1906, May & June	10	2	2·5	2·5	2·5	

This table shows that there is apparently no essential difference in the growth in the two marking experiments A and B. The latter (B) displays the peculiarity however that the first three plaice recaptured, which had only been marked 4 months, have increased more in this short time than the others which had been marked 6—10 months on recapture. Looking closer we see that the first three were retaken close to where they were liberated, whilst the others had made long migrations (to ca. 240 miles). It is thus possibly the long migration in a short time which has caused the increase in growth to be smaller than in those specimens which had not migrated, but I am quite unable to say anything certain on the matter as the material is too small. That the latter have grown relatively so much in the course of only 4 months is perhaps due rather to the fact, that the temperature of the water on NE Iceland where they were liberated and recaptured is relatively high just at the end of summer and in the autumn (that is, in the period between liberation and recapture), whilst very low temperatures prevail on the east coast during the rest of the year. It may be that the plaice on the north-east coast grow mainly in these months; in hydrographical regard this period is summer[1] at NE Iceland and the plaice marking experiments at any rate point without straining in the direction mentioned.

Migrations

A glance at Chart I shows at once that the plaice liberated on the north coast act quite differently as regards migrations from those liberated on the east coast. Practically all of the former went westwards and practically all the latter went southwards. One thing however is common to both experiments and deserves to be specially emphasized, namely, that the plaice have moved in the direction of the warmer water, and what is noteworthly, they have taken the shortest way to the warm water from the two different localities where they were liberated.

The plaice which has migrated furthest in the shortest time was one marked in July in Vopna Fjord and retaken the following July on the south coast at Portland (No. 2470). It has thus wandered at least ca. 240 miles in 6 months, a distance equal to from Scotland across the North Sea to SW Norway, which means a rate of ca. 1·4 miles per day. The plaice liberated in Vopna Fjord have migrated far on the whole, apparently further than those liberated in Skiálfandi Bay. The one that has covered the greatest distance of all was marked in Vopna Fjord and retaken at the Vestmanna Islands (marked on the Chart as "E. 9"), a distance of at least ca. 280 miles.

It may seem remarkable that with exception of the few retaken close to where they were liberated, none of the plaice marked in Vopna Fjord were retaken on the east coast. It is only right down in the south at Ingólfshöfði that the most were retaken. This will in fact be very readily understood however, when it is explained that practically no trawl fishery is carried on along the whole of the east coast

[1] Cand. mag. I. N. Nielsen, the hydrographer of the "Thor" informs me that November is probably the warmest month at NE Iceland (round Lánganes). Further west, off the north coast, the warmest month is somewhat earlier (in September) and still earlier (August) on the west coast.

south of Vopna Fjord and Héraðs Bai, chiefly on account of the rough nature of the bottom. It is only when the plaice migrating southward from Vopna Fjord have reached the south coast where there is an intensive plaice fishery (especially in winter and spring) that they are in danger of being recaught, as the marking experiments have now shown.

Comparing the results of the two experiments (see Chart), it will seem very peculiar that the plaice marked on the north coast, all of which so to speak migrate westwards towards the warmer water, appear to migrate considerably slower in general than those liberated on the east coast. That this is the case can be readily seen from the numbers given on the Chart, which indicate how many months the fish in question has been in the sea between the marking and recapture.

It has to be remembered in this connection that the plaice liberated on the north coast have undoubtedly, on account of the bathymetric conditions, to make a very considerable circuit in order to get from Skiálfandi Bay to the west coast, whilst those marked in Vopna Fjord are quite differently situated in this regard. Following the lines of depth on the north coast we see that tongues of considerable depths penetrate right into the numerous bays on this coast, so that to avoid these depths the plaice are obliged in the main to follow close to the coast line, which naturally greatly lengthens their journey. That this has really been the case is also indicated by the recaptures of plaice on the north coast, two of them having been retaken right in at the head of the long and narrow Eyja Fjord (ca. 18° L. W,) and one far into Húna Bay (ca. 21° L. W). It should also be remarked in this connection, that although the plaice migrating westward along the north coast do not seem to reach further than Isa Fjord (NW coast), this may well be due to the fact that a relatively great fishery is carried on there, whereas further south off the west coast (at any rate as far as Faxa Bay), trawling can only be quite local on account of the nature of the bottom. It may well be, therefore, that many of the marked fish have really gone further south along the west coast than the Chart seems to indicate, thus e. g. as far as the large Breiði Bay (ca. 65° N) which is so filled with rocks and small islands that fishing and even trading is in general very difficult. No plaice which had passed Staalbjerg Huk (Bjargtangar) (c. 65°50′ N) on its way south would therefore be recaught before it had reached Faxa Bay (ca. 64°30′ N). Nevertheless, there is undoubtedly a great number of plaice in this Breiði Bay, as at few places at Iceland did we find so many plaice eggs as at the mouth of Breðii Bay, when in April 1904 the "Thor" sailed round the whole of Iceland in order to study the distribution of the pelagic eggs of the economically important fishes.

Intensity of the plaice fishery

In this regard also the marking experiments give some interesting results in comparison with the conditions in other waters where a place fishery is prosecuted.

In Skiálfandi Bay on the north coast 280 plaice were marked in June 1903, and of these 14 specimens have been recaptured up to Jan. 1st, 1907, that is 5 %. Of the 494 plaice marked in Vopna Fjord in July 1905, 15 or 3·04 % have been retaken up to the same date, but this experiment can hardly be considered completed as yet, so that the latter percentage may well be increased somewhat before the final results are to hand. In any case, the percentages found are rather low in comparison with the conditions found by Dr. A. C. Johansen in the North Sea, Skager Rak and Kattegat (Cf. p. 9).

In comparing these figures it should be mentioned that the plaice at Iceland were marked in quite the same manner as in the other Danish investigations (North Sea, Skager Rak and Kattegat) made by Dr. A. C. Johansen, and the fishing was carried on with the same small ottertrawl (50 feet), short hauls of ½—1 hour being made. Further, so many plaice were obtainable at the localities where the experiments were made, that no fish was ever put out again which we were not certain was quite strong and

able to live. For the rest, the fish were liberated at exactly the same spot where they were fished and practically all were large, marketable fish, so that there is no reason whatever to doubt that the principal reason for not obtaining more recaptures must be, that the areas inhabited by the plaice at Iceland are far from being fished with the same intensity as those in the North Sea, Skager Rak and Kattegat. And that this is not the case is due again, partly to the fact that the nature of the bottom over large tracts is against the fishing, and partly for the reason that there is practically no coast fishing for plaice at Iceland in comparison with that for example in the inshore waters of Denmark and Germany.

In agreement with these conditions, we also find that the Iceland marking experiments differ in several regards from what one is accustomed to in the North Sea, Skager Rak and Kattegat.

In the first place, for example, it is striking that so few fish were retaken in the neighbourhood of the locality where they were liberated and in the second place, that so long a period intervened between the liberation and the date when the first of the marked fish was retaken, namely, 1 year in the north coast experiments and 3 months in the east coast experiments. As a general rule, a very large percentage of the fish recaptured at all are taken near the place of liberation shortly after liberation. A second peculiarity is that many of the marked plaice have been unusually long in the sea before they were retaken, namely, up to 3 years or more.

It is of no small interest to ascertain by whom the marked plaice at Iceland were retaken. Taking each experiment by itself we have the following results.

Experiments in Skiálfandi Bay on the north coast
(fish retaken on the north and north-west coast)

No. of fish retaken	Retaken by British fishermen		Retaken by Icelandic fishermen	
	number	%	number	%
14	10	71·43	4	28·57

Experiments in Vopna Fjord on the east coast
(fish retaken on the south coast and in Vopna Fjord)

No. of fish retaken	Retaken by British fishermen		Retaken by German fishermen		Retaken by Icelandic fishermen	
	number	%	number	%	number	%
15	8	53·33	6	40	1	6·67

We see from this that on the north and north-west coasts the British and Icelandic fishermen have been the only ones to take any marked fish, whilst the German had a shore on the south coast. This corresponds remarkably well with the fact, that whilst the British trawlers fish everywhere round the coasts of Iceland, the Germans restrict themselves in general to the south coast, especially on the tract from Ingólfshöfði to Portland. That so many of the marked fish were retaken by the Icelandic fishermen has surprised me somewhat, but the reason is probably because the experiments were made just on the north coast where there are so many bays into which the plaice can wander. On the south coast scarcely a single plaice should have been taken by the Icelanders, as can be seen also from the chart.

Taking both experiments together, we obtain the following subdivision of the catches according to nationality.

Retaken by British fishermen..... 62·07 %
— - German — ..... 20·69 -
— - Icelandic — ..... 17·24 -

This gives probably a fairly good idea of the actual conditions, as by far the largest part of the plaice taken at Iceland are fished by British trawlers, but if the fishery round the whole of Iceland be considered the percentage given for the Icelanders is certainly too large, since along the whole south coast where foreign trawlers chiefly work practically no plaice fishery whatever is carried on by the Icelanders.

III. MARKING EXPERIMENTS ON THE COD *(GADUS CALLARIAS)*

These come under four divisions A, B, C and D. Of these the first two were carried out in the year 1904 on the east coast, the last two in 1905 on the north coast. In contrast to the plaice experiments the cod used were not adult fish, the majority having a length of from 40 to 60 cm. Most of the fish marked belonged therefore to the sizes called by the Icelandic fishermen "stútungar" and "þýrsklingar" (see my work: "Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903", Pl. VIII, where measurements are given of the cod taken in summer-time on the east coast). Of these (and of the still younger) size-groups quite phenomenal quantities are found in the summer on the east and north coasts in the fjords, in spite of the fact that no or few cod spawn there but on the south coast (especially on the tract between Vestmanna Islands and Reykianes) and west coast (see text figure p. 20), from which they are carried as pelagic fry by the currents in the summer eastwards along the north coast and thence to the east coast. The whole drift of the pelagic stages of the cod round the island was closely investigated by the "Thor" in 1903—1905, especially in 1904, and we knew therefore with certainty, (1) that the young of the first year were carried passively from the spawning places in the warm Atlantic water to the cold water on the north and east coasts and further, (2) that the ripening fish for the sake of spawning leave the cold water and seek back to the south and west coasts. The question was then, whether the I, II, III and IV groups, which are not yet mature, pass the winter in the ice-cold water on the east and north coasts or whether they seek at this season back to the warmer water. As regards the I group the question was soon solved, as so early as April in 1904 I found enormous quantities of cod of this group in the fjords on the east coast, where the water at this season is still ice-cold (see later p. 15). As regards III and IV, the endeavour was to solve the question by means of marking experiments, which were therefore as mentioned mainly undertaken on fish belonging to these groups ("stútungar", partly also "þýrsklingar"), unlimited quantities of which could easily be obtained on the east and north coasts at the time when the experiments were made (July—August).

Experiments on the east coast (A, B)

The marking experiments A were undertaken as already mentioned in July 1904 in Loðmundar Fjord on the east coast (see p. 4) and only fish taken by hooks in shallow water, ca. 10—12 fathoms, were marked. With regard to the cod fishery on the east coast it may be mentioned, that the fishery only begins there late in the year, long after the beginning of the great cod fishery on the south coast. Thus the fishery does generally not attain to any importance before June. It is at its maximum generally in July

Particulars of Liberation. Date. Locality. No. of Fish etc.	Particulars of Recovery										
	Date	Nr. on Label	Locality reported	Central Position (Approximately) N	W	Fishing Vessel	No. of months between Liberation and Recovery	Initial Size cm.	Ultimate Size cm.	Sent in by
A. 1904 July 25 297 cod No. 1601-1941 Loðmundar Fjord 65° 21·5′ N 13° 42′ W Depth 12-16 fms.	1904 July 29	1798	Off Húsavík East Iceland	.....		Icel. open boat	..	102	..	Commander of H. M. S. "Hekla"
	» » 30	1912	3 miles ESE of Alftavík — 40 fms.	65°22′	13°28′	» »	..	80	..	Bjarni Sæmundsson, Reykjavík
	» August 5	1761	1 mile N of Skálanes, Seyðis Fjord — 30 fms.	65°19′	13°40′	» »	..	82	..	— —
	» » 5	1856	1 mile E of Húsavík — 17 fms.	65°24′	13°35′	Færoese »	..	64	..	— —
	» » 6	1664	2 miles S of Alftavík — 29 fms.	65°22′	13°36′	» »	..	81	..	Jens Andreasen, Thorshavn
	» » 9	1886	Off Skálanes — ?	.....		» »	..	63	..	— —
	» » 12	1850	5 miles SE of Húsavík — 60 fms.	65°22′	13°29′	Iceland. »	..	76	..	Bjarni Sæmundsson, Reykjavík
	» » 16	1738	4 miles E of Loðmundar Fjord — 40 fms.	65°21′	13°31′	Færoese »	..	78	..	— —
	» 18	1872	4 miles N by E of Dalatangi — 60 fms.	65°20′	13°29′	Icel. open boat	..	79	..	— —
	19	1893	3 miles E of Alftanes — 40 fms.	65°23′	13°30′	» »	..	60	..	— —
	» » 19	1881	— — — 40 fms.	—	—	» »	..	66	..	— —
	» » 24	1787	8 miles E of Dalatangi — 80 fms.	65°17′	13°14′	» »	1	66	..	— —
	» » 26	1745	2 miles SE of Dalatangi — 50 fms.	65°16′	13°29′	» »	1	63	..	— —
	» Septb. 2	1815	4 miles N of Dalatangi — 75 fms.	65°20′	13°29′	» »	1	51	..	— —
	» » 3	1816	4 miles NE of Barðneshorn — 60 fms.	65°13′	13°22′	» »	1	41	..	— —
	» » 5	1714	5 miles E of Seyðis Fjord — 65 fms.	65°19′	13°28′	» »	1	60	..	— —
	» » 16	1900	N of Hafranes, Reyðar Fjord — 30 fms.	64°58′	13°48′	» »	1	69	..	— —
	» » 26	1730	2 miles SE of Dalatangi — 55 fms.	65°15′	13°29′	» »	2	42	..	— —
	» » 28	1610	Seyðis Fjord — 30 fms.	65°19′	13°40′	» »	2	82	..	— —
	1905 April 17	1733	8 miles E of Dalatangi — 60 fms.	65°15′	13°13′	» »	9	50	..	— —
	1905 June 28	1709	Mouth of Seyðis Fjord East Iceland 20—30 fms.	.....		» »	11	50	..	— —
	» July 23	1732	1 miles SSW of Dalatangi — 15 fms.	65°15′	13°33′	» »	12	45	..	— —
	» » 27	1675	Bakka Fjord — 25 fms.	66°03′	14°50′	Færoese »	12	42	..	O. Finsen, Thorshavn
	» August 29	1743	40 miles N by W of Lánganes — 110 fms.	67°02′	14°54′	Fær. cutter	13	52	63	Jens Andreasen, Thorshavn
	1906 Septb. 7	1736	12 miles NW by W of Grímsey North Iceland 100 fms.	66°37′	18°26′	» »	25	55	80	Joh. Elias Johannesen, Midvaag
B. 1904 July 28 56 cod No. 1942-1998 69 cod No. 1501-1583 35 cod No. 1537-2000 34 cod No. 1522-1903 Héraðs Bay 65° 41′ N 14° 10′ W.	1904 Septb. 12	1591	1 mile NW of Bjarnarey East Iceland 25 fms.	65°48′	14°18′	Icelandic open boat	2	69	..	Bjarni Sæmundsson, Reykjavík
	1905 July 24	1972	14 miles NE by E of Kollumúli East Iceland 93 fms.	65°55′	13°54′	French schooner of Paimpol	12	50	61·2	Ch. Rabot, Paris
	1906 Aug. 25	1537	East Iceland 120 fms.	66°30′	13°01′	Færoese cutter	25	60	78·5	Jens Andreasen, Thorshavn

and then gradually decreases until towards Christmas or even earlier it is quite over. It consists partly of a coast fishery in the fjords and in the neighbourhood of the coasts carried on from small boats by the fishermen of Iceland and the Færoes, and partly of a sea fishery which in contrast to the coast fishery is based chiefly on the large, spawned fish. This sea-fishery is prosecuted chiefly by the Færoese fishermen, who work at the Færoes during the spring fishing period, and by the French coming from the south coast in pursuit of the large shoals of spawned cod which migrate in summer to the colder waters on the east coast. On the other hand, the Icelanders do not take part or only to a small extent in the sea fishery off the east coast which is restricted to the summer months, namely, from May—June to September.

It should be understood that when our marking experiments were carried out on the east coast, namely, in July 1904, this was the time when enormous quantities of cod of all years groups except the young of the year were present and when the coast fishery of the Icelandic and Færoese fishermen was in full swing.

The second cod marking experiments on the east coast (B) were made a few days after the first, not however in Loðmundar Fjord but in the somewhat more northerly Héraðs Bay, a quite open bay and one of the few places on the east coast where the bottom is suited to trawl fishing. Here also there were enormous quantities of medium-sized cod (chiefly of the III and IV groups) when the marking experiments were made, so that it was extremely easy to procure material. The cod were taken in short hauls with a 50-foot ottertrawl. During the operations the trawl was not brought on board, the cod-end with the catch in it being allowed to hang in the water, and one of the ship's boats was launched. The fish were then marked from the boat, being taken one by one from the trawl, in which a small hole was cut sufficiently large for the purpose. In this way the fish were only out of the water during the few moments required for fixing on the marks, and to judge from the speed and force with which they shot off towards the bottom after being liberated, they were quite lively and strong. Nevertheless, on comparing the percentages of fish recovered from the experiments A and B, we cannot help noticing an obvious difference between the two. Thus, 8 % of the cod marked in Loðmundar Fjord (line cod) were retaken, whilst only 1·6 % of those marked in Héraðs Bay (trawl cod) were recaptured. It is possible therefore that some of the latter were damaged somewhat by the trawling, but it must also be emphasized that the conditions for their recapture were not nearly so favourable, as there was but extremely little fishing for cod at the place where they were set out (Héraðs Bay which is quite open to the sea), whereas in and around Loðmundar Fjord when the marking experiments were made the cod fishery was just at its maximum. In agreement with this we find also that by far the most of the cod from Loðmundar Fjord were taken close to the place where they were liberated, which happened to none of the cod from Héraðs Bay (se Chart), and if we calculate the percentage of fish retaken only in the following season, we find that the difference between the experiments A and B becomes much less. Thus, of the Loðmundar Fjord cod (297) 6 specimens or ca. 2 % were retaken in the following seasons, whilst of the 194 Héraðs Bay cod 2 specimens or ca. 1 % were then recaptured.

For this reason I am inclined to think, that the cause of so few being recaptured in the Héraðs Bay experiment was not that the fish was trawled, but chiefly that there was practically no fishery at the place where they were liberated.

Growth

I have already (l. c.) published a contribution on the growth of the cod at East Iceland. I mentioned there how the quantities of small cod found in the fjords in the summer were quite unusually large, and I remarked on the fact that cod of the I group (young of the previous year) were unusually small. It can be seen for example from the numbers given, l. c. p. 76, that the I group in Seyðis Fjord on May 23rd, 1903, were ca. 9 cm., on July 23rd, 1903, ca. 12—13 cm. and on the 19th—23rd Sept., 1903, ca. 15—16 cm. I mentioned further that the 0 group (i. e. the young of the year) were absent in the summer on the east coast as also naturally in the spring.

As these measurements of the I group have caused some astonishment[1] on account of the small size of the cod, perhaps also some doubt whether it was really the I group and not the 0 group, I may here give some further details in explanation of the matter. If the small cod mentioned, which were in July ca. 12—13 cm. long and in May ca. 9 cm., did not belong to the I group but to the young of the year, they ought to have been much smaller in April, if the cod spawn in March—April at Iceland.

In 1904 I was early at Iceland with the "Thor" and immediately got a large number of cod measured. Thus on April 26th, 1904, we made 4 hauls in Seyðis Fjord with the eel-seine depth: 12 fathoms (surface-temperature 1·5°, bottom-temperature 1·3°), and took 344 cod varying from 6—25 cm.

[1] This has appeared partly in various citations of my book, partly in a work by T. W. Fulton: On the rate of growth of fishes (24th Annual Report, Fishery Board for Scotland, 1905, p. 211—12).

in length. The measurements are given below. On April 30th, 1904, we made 5 hauls in Eski Fjord (65°04′ N., 13°59′ W.) with the eel-seine from 7—10 fms. In one of these hauls 5810 cod were taken varying in length from 5—25 cm. The temperature of the water was as in Seyðis Fjord.

Seyðis Fjord 25. IV. 1904			Eski Fjord 30. IV. 1904		
Cm.	number		Cm.	number	
25	1	II group	25	1	II group
-			-	3	
23	1		23	1	
-	3		-	2	
21	6		21	4	
-	16		-	5	
19	20		19	2	
-	17		-	1	
17	7		17		
-	8		-		
15	4		15	1	I group
-	2		-	5	
13			13	4	
-			-	22	
11	4	I group	11	76	
-	13		-	307	
9	34		9	1354	
-	66		-	2356	
7	104		7	1524	
-	38		-	151	
5			5	1	

From these figures every one will judge that the cod in question, which were about 7—8 cm. long, could only belong to the previous year and not to the young of the year. The latter we did not find at the east coast, in spite of numerous hauls, before August[1]. They were then taken pelagically off the northerly part of the east coast and had a length of ca. 4 cm. In September they begin to appear in the fjords and then have an average length of 4—5 cm.

We thus have the following data to judge of the growth on the east coast in the first and second year.

Seyðis Fjord

		length
September	ca.	4½ cm.
April	-	7 -
May	-	9 -
July	-	13 -
September	-	16 -

We see from this that the growth from September to the following September amounts to ca. 12 cm., and that in the winter when the water on the east coast is cold it is only very small, namely, ca. 2½ cm. from September to the end of April.

[1] On the other hand, the young of the year occurred in quantities pelagically in May—June 1904 on the west coast and in July - August 1904 in quantities on the north coast.

I may remark expressly that it is in the cold water of the east coast that the growth is so small. In the warm Atlantic water at South Iceland and the Færoes, where the conditions are fairly uniform throughout the year, the cod grow much more in their first year, just as is the case in more southerly waters.

The marking experiments do not give much information regarding the growth of the cod, as most of the fish recovered have obviously been measured either wrongly or in a different manner from that used on the "Thor" (from the tip of the snout to the posterior margin of the tail fin). This applies especially to the fish measured by the Icelandic fishermen[1], whereas those measured by the Færoese and French fishermen, who have had the printed scheme in their hands, are probably more trustworthy. I give therefore only the measurements sent me on the printed schemes, where it was distinctly asked to state the length from the tip of the snout to the end of the tail. In this way only 4 specimens can be used. From these we find that the cod

No. 1972 has grown in 12 months from 50 to 61·2 cm.
- 1743 — — - 13 — — 52 - 63 —
- 1537 — — - 25 — — 60 - 78·5 —
- 1736 — — - 25 — — 55 - 80 —

The growth was thus about 10 cm. in the year.

Migrations

Of the (immature) cod marked on the east coast 28 specimens in all have been recaptured and of these 28, 20 were retaken in the same fishing season as the marking experiments. The remainder, i. e. 8 specimens, were only retaken in later fishing seasons, that is to say, they have remained one or more winters uncaught. These 8 specimens which were all at least one winter in the sea are thus well suited to answer the question, which was the main object of the marking experiments, namely, whether the earlier years groups of the cod especially the groups called "Þyrsklingar" and "stútungar" pass the winter on the east and north coasts, where very low temperatures (about 0°) prevail throughout the whole winter and spring, or whether they seek the warmer Atlantic waters on the south coast for their winter residence.

We learn from the chart that all the 8 cod have remained off the east and north coasts[2], and the question may therefore be regarded as in the main solved.

The marking experiments show clearly another condition, namely, that the cod tend gradually to move out into deeper water, as can be seen from the details given in the list regarding the fish retaken (see p. 14).

For the rest, these young cod with which the experiments were concerned are apparently somewhat irregular in their migrations, though on the whole there seems to be a tendency to move northwards and westwards from the east coast, that is, in a direction contrary to that of the Irminger Current, but the movement seems to be slow.

Intensity of the fishery for the young cod

Of the 297 cod marked in Loðmundar Fjord, 25 specimens or ca. 8·4 % were retaken up to Jan. 1st, 1907. Of the 194 cod marked in Héraðs Bay 3 specimens or ca. 1·6 % were retaken up to the

[1] The Icelandic fishermen consider as "Maalsfisk" those that measure 18 Da. inches with the head removed.

[2] If the cod or some of them had migrated to the south or west coasts, the chances for their recapture would have been at least just as great, because, as is known, the fishery there is carried on with much greater energy than on the east and north coasts, where the fishery is mainly restricted to the summer and autumn.

same date. As mentioned above I ascribe the much fewer number recaptured in the second experiment to the fact, that at the place where the experiment was made (Héraðs Bay) practically no coast fishery is carried on, in contrast to the conditions in thes urroundings of Loðmundar Fjord, where the coast fishery (from Seyðis Fjord etc.) was just being prosecuted with great energy when the experiment was made. When therefore the two experiments A and B are combined, as in the following table, it has to be remembered, that the one was made at a place where an extensive fishery from small boats was proceeding, whilst the other was made in an open bay where there was practically no cod fishery.

Of the 28 cod recaptured, 24 were taken during the coast fishery with open boats, whilst the other 4 were taken at the sea fishery by sea-going vessels.

The numbers retaken were distributed amongst the different nationalities of fishermen as shown by following table.

Summary of the recaptures of the young cod marked on the east coast (A, B)

Nationality	Fishery with open boats (coast fishery)		Fishery with decked boats (sea fishery)		Total	
	No. of fish retaken	Percentage	No. of fish retaken	Percentage	No. of fish retaken	Percentage
Iceland	19	79·2	0	0	19	67·9
Færoes	5	20.8	3	75·0	8	28·6
France	0	0	1	25·0	1	3·5

We see from this, that the cod fishery (at least for the younger groups of cod) is carried on by quite a different set of fishermen from the plaice fishery. Thus the English and the Germans are quite absent whilst we now have the Færoese and the French. For the rest, the numbers recaught give probably a somewhat correct picture of the true conditions on the east coast. We see, for example, that the cod taken by open boats (coast fishery) are divided by the Icelanders and the Færoese, the latter being Danish subjects having the right to fish on Icelandic territory, and it is by no means a small percentage of the fish caught during the coast fishery, which is taken by the Færoese, namely, 20·8 % against the Icelanders 79·2 %.

The conditions in the sea fishery on the east coast are essentially different from those for the coast fishery. We see for example that not one of the cod recaptured has been taken by the Icelanders themselves, but this also corresponds to the actual conditions, as curiously enough no sea fishery or practically none is carried on off the east coast by the Icelanders. The majority of the cod taken in the open sea come from the Færoese fishermen (75 %), whilst 25 % fall to the shore of the French. This is also in fair agreement with the actual conditions, as the sea fishery for cod off the north coast is carried on chiefly by the Færoese and French cutters and schooners. Nevertheless, from my knowledge of the conditions I would have expected a relatively greater percentage of fish from the French side, but the reason for this is perhaps, that most of the fish marked were of the younger, smaller groups, whereas the French seek mainly for the largest cod in deeper water further from the coasts. It is possible also that the French more than the Færoese have fought shy of the responsibilities attached to the forwarding of marks and information.

Finally, it need only be mentioned that of the cod liberated in Héraðs Bay, a place somewhat out of the way of the Icelandic coast fishery from open boats, only one third of the specimens were retaken by the Icelandic fishermen, the remaining two thirds being divided by the Færoese and French. In this also it is probable that we see the actual conditions prevailing on the east coast with the exception of such places, which on account of their being near to the larger Icelandic villages, are specially well fished by the Icelandic open boats.

Experiments on the north coast (C, D)

These were made in the summer of 1905 partly in Skaga Fjord (C) where 391 cod were marked, most of them being of the III and IV group, thus of the same size as those of the east coast, partly at Hrísey in Eyja Fjord (D) where a small number (26) were marked. As can be seen from the accompanying list, 10 specimens in all (2·2 %) have up to the present been returned, all of them taken by Icelandic open boats. Of these 10 cod, 6 have passed a winter in the sea, and of these 6, 4 had remained on the north coast whilst the other two had migrated westward to Isa Fjord. It seems that the cod of the III and IV group present on the north coast in summer in great quantities also mostly pass the winter there, in spite of the fact that the temperature of the sea in winter and spring is very low as on the east coast. For the rest, the migrations on the north coast also seem to show a certain amount of irregularity, which appears in this that some of these young cod have migrated eastwards, others westward whilst others again have remained in the same fjord where they vere liberated.

Particulars of Liberation. Date. Locality. No. of Fish etc.	Particulars of Recovery								
	Date	No. on Label	Locality reported	Central Position (Approximately)	Fishing Vessel	No. of months between Liberation and Recovery	Initial Size cm.	Ultimate Size	Sent in by
				N W					
C. Skaga Fjord 1905 Aug. 10-18 376 cod No. 2601-2976 (66° 01′ N 19° 32′ W) and 15 cod No. 2500-2509, 2517-2520, 2524 (65° 56′ N 19° 26′ W	1905 Aug. 28	2925	6 miles SW of Málmey N-Iceland 45 fms.	65°56′ 19°35′	Icel. open boat	0	51	..	Bjarni Sæmundsson, Reykjavík
	» Septbr. 22	2737	Eyja Fjord » » 8 fms.	65°45′ 18°04′	» »	1	49	..	— —
	1906. May 15	2898	N of Vigur, Ísafjarðardjup NW- » 80 fms.	66°08′ 22°55′	» »	9	46	..	— —
	» » 21	2748	N of Gullhús, Ísafjarðardjup NW- » 80 fms.	66°10′ 23°02′	» »	9	50	..	— —
	» July 16	2692	Off Hofsós, Skaga Fjord N- »	65°54′ 19°25′	» »	11	41	..	— —
	» Aug. 18	2658	Almenningsnöf, W of Siglu Fjord N- » 40 fms.	66°10′ 19°08′	» »	12	42	..	— —
	» Octbr. 20	2912	Off Hofsós, Skaga Fjord N- »	65°54′ 19°25′	» »	14	52	..	— —
	» » 13	2509	1 mile of Grimsnestangi, Eyja Fjord N-Iceland	66°03′ 18°18′	» »	14	41	..	— —
D. Eyja Fjord 1905 Aug. 16 & 22 26 cod No. 2521-2523, 2525-2547 Hrísey (65° 58·5′ N 18° 20′ W)	1905 Septb. 27	2523	½ mile SW of Hrísey, Eyja Fjord N-Iceland 10 fms.	65°59′ 18°22′	Icel. open boat	1	50	..	Bjarni Sæmundsson, Reykjavík
	» Octb. 21	2539	2 miles NW of Hrólfskér, Eyja Fjord N-Iceland 70 fms.	66°07′ 18°26′	» »	2	40	..	— —

With regard to the nationality of the fishermen by whom the fish were retaken, we see that in contrast to the east coast conditions only the Icelandic coast fishermen are in evidence. The Færoese have no coast fishery from open boats here on the north coast as on the east coast. It is curious further, that none of the marked fish have up to the present, been caught by the Icelandic or Færoese cutters which fish off the north coast in summer, but marks may possibly come in later, and in any case to judge from the other experiments this experiments can scarcely as yet be considered as concluded.

IV. SUMMARY

Whilst the south and south-west coasts of Iceland are washed throughout the whole year by the warm Atlantic water, this is not the case on the east and north coasts where the influence of the polar water is felt. Here the temperature of the water is very low, about 0° C., for the greater part of the year,

especially all through the winter and spring, that is, at the spawning time of the cod and plaice. The principal reason why, the spawning of these species takes place mostly on the south and west coasts is to be found in these conditions.

In the summer a branch of the warm Atlantic current (Irminger Current)[1] moves eastwards along the north coast, reaching towards the end of summer to the northern part of the east coast. This warm east-going current is of fundamental importance for the fish-life on the north and east coasts, as enormous

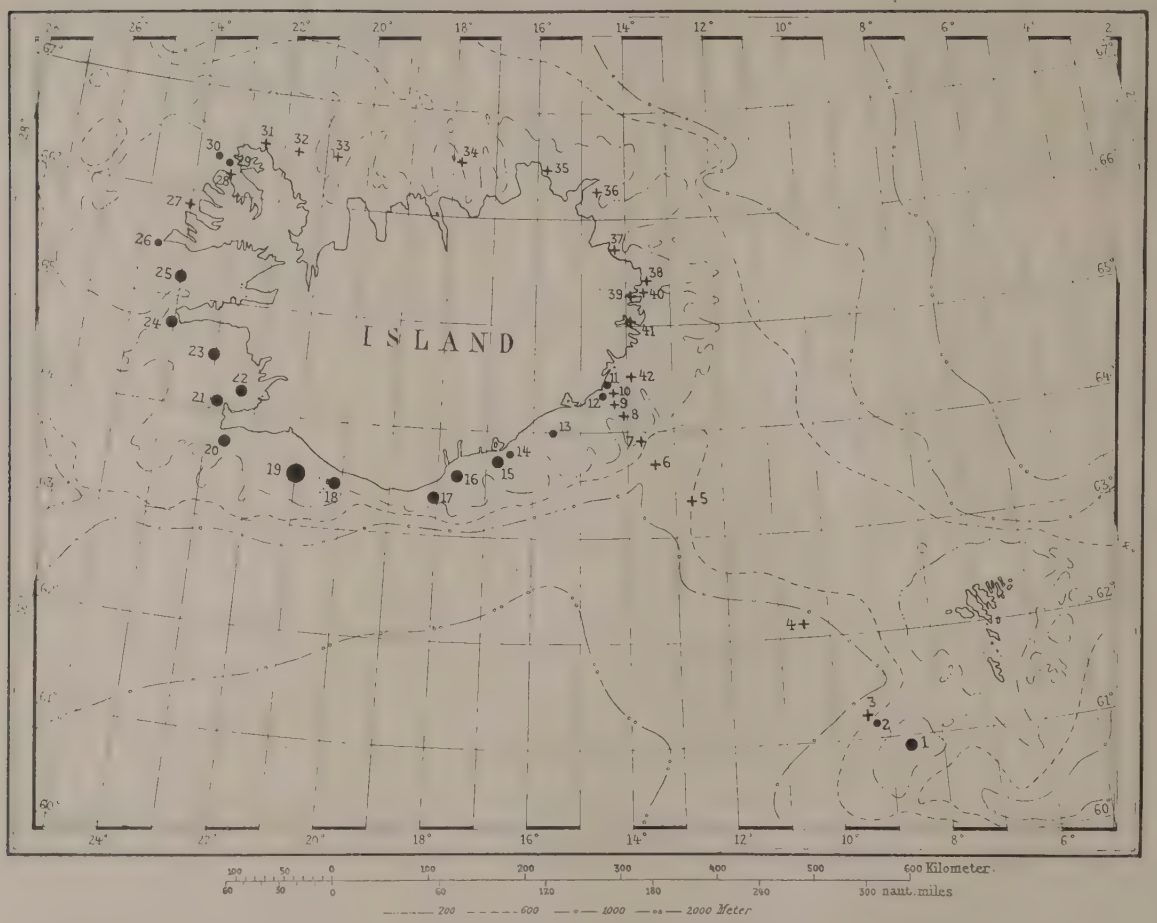


Chart showing the distribution of the cod eggs round Iceland in April 1904 according to the investigations of the "Thor" (Stations 1—42). The investigations were made by means of pelagic nets. At the stations marked + no cod eggs were found.

masses of pelagic fish young are carried passively by it away from the spawning places and gradually as they grow older seek the bottom on the coasts and in the fjords of the north and east coasts.

If now investigations, such as those I have made with the "Thor", are carried out in the following spring and summer to ascertain the distribution of the one year old fish on the coasts of Iceland, we find this peculiar thing for example for the cod, that but a relatively small number of the fry is found on the south and

[1] F. N. Nielsen: Contributions to the hydrography of the waters North of Iceland (Meddel. fra Komm. f. Havunders., Serie: Hydrografi, Bind I, No. 7, 1905).

south-west coasts, where nevertheless they have been spawned. On the other hand, we find enormously large quantities of the one year old cod on the east and north coasts and in the fjords there, i. e. far from the spawning places, larger perhaps than at any other place in the world (cf. for example the haul with the eel-seine in Eski Fjord on April 30th 1903, p. 16 above).

In the light of the main results thus briefly given of the "Thor"s investigations on the fish young at Iceland in the years 1903—05, the marking experiments must be understood and considered.

With regard to the nature of the fish marked (plaice and cod), prominence should be given to the fact that whilst most of the plaice were old fish, which were mature, the cod marked were mostly young, immature specimens, belonging chiefly to the years groups called by the Icelandic fishermen "þýrsklingar" and "stútungar" (mostly ca. 40—60 cm.)[1]. It is important, to remember this in drawing conclusions from our marking experiments.

As the first main result of the marking experiments at Iceland may be mentioned that all the fish retaken were caught at Iceland itself; none of them have left the Iceland banks to pass over the ocean to other banks.

For the rest, I shall deal with the cod and plaice marking experiments each by themselves, as the questions are different for the two species. With regard to details, reference may be made to the above detailed descriptions; here only the most important of the results won by the marking experiments will be mentioned.

Cod experiments

The main object of the marking experiments was to settle the question, whether the earlier, immature stages of the cod pass the winter in the cold water on the east and north coasts, or whether like the adult, spawning fish they migrated yearly to the warm Atlantic water. This question may now be said to have been in the main solved, as the marking experiments show that these earlier stages of the cod were retaken on the east and north coasts even 1—2 years after liberation. In spite of the low temperature in winter, the young cod thus pass the winter on the east and north coast. The demonstration of this phenomenon is a matter of no small importance, both in practical and scientific regards. It is of importance for the practical fishery, because it seems from this as if the coast fishery for the younger cod could begin, for example on the east coast, earlier in the year than it does in general at present, where usually the fishery only starts when the shoals of large, spawned cod from the south and west coasts have begun to appear. The marking experiments show also that the coasts and fjords on the east and north must be regarded as the most important rearing grounds for the cod at Iceland, a fact which should tend to quieten the fears of those Icelandic fishermen who think that the foreign trawlers are destroying the stock of fish. Since, if it is the case that the cod grow to their full size and maturity mainly in the fjords and coastal waters on the east and north coasts, where but little trawling takes place on account of the nature of the bottom etc., then we see at the same time that they are free from the efforts of the foreigners during the greater part of their growth. It seems therefore that the natural conditions themselves are taking care in a very effective manner that the actual mode of fishing however powerful it may be will not destroy or even essentially diminish the stock of cod at Iceland.

As to the intensity of the cod fishery off the east coast and shore taken in it by the different nationalities see p. 18.

[1] That no experiments with adult cod, which would have been of considerable interest, were made by the "Thor" was due to several difficulties connected with the obtaining of these large fish (thes pawning cod at Iceland are about 80—90 cm. long) in quantities in somewhat shallow water, where they are mainly only found in early spring during spawning. If the fish are taken from deep water (in the summer they are mainly only found in deep water), it is difficult to get them to sink to the bottom again after marking.

Plaice experiments

There was no difficulty in procuring specimens of plaice for marking which were either nature or approaching maturity. The experiments were therefore made mostly with the older fish which were considered as ready or going to spawn. As localities for the experiments were chosen the north and east coast where the stock of plaice is relatively intact, and one of the main objects of the marking experiments was then to determine whether the plaice on those coasts (particularly the east coast, where the water is coldest) actually undertook for the sake of spawning the long migrations necessary to reach the warm Atlantic water, as appeared to be the case from the distribution of the young of the year as determined by the "Thor".

A second object of importance was to obtain data for comparison with other waters, in regard to the intensity with which the plaice fichery is carried on at Iceland, especially on the northern coasts, where the stock is probably more intact than at most other places in the world (see p. 7 regarding this).

With regard to the first of these questions, even a hasty glance at Chart I will show clearly that the object of the migrations of the marked plaice is to reach the warm water. The marking experiment in Vopna Fjord especially shows this in an excellent manner, but the experiment in Skiálfandi Bay points in the same direction. And it is worthy of remark, that the plaice in both marking experiments have migrated by the shortest route to the warm water, namely, from Vopna Fjord southwards along the east coast and from Skiálfandi Bay westwards along the north coast.

These marking experiments are of considerable scientific importance, as they give us the direct proof that even a fish, which one would not have taken beforehand as specially adapted for movement, really undertakes the long migrations from the cold water, where it has grown up, till it meets the Atlantic water and there finds the conditions favourable for the accomplishment of spawning.

That the same is the case for the cod has not been directly proved by marking experiments on mature fish, but it appears to be so as is shown by the chart p. 20 on the distribution of the cod eggs at Iceland.

With regard to the information gained from the marking experiments concerning the intensity of the plaice fishery and shore taken in it by the different nationalities, reference may be made to p. 12—13 above.

Some biological features of importance

I have remarked on another occasion[1] that fishes at the spawning period are often much more sensitive to external conditions than at other times, so that when about to spawn for example they require quite definite conditions of temperature and depth, although at other stages of their life, for example during growth, they are able to live under quite different conditions.

The investigations at Iceland, where the natural conditions are so extremely different on the different coast, are specially well suited to throw light on these question, and the present marking experiments together with the other investigations of the "Thor" give therefore definite points of support in this regard. These are as follows.

We have seen how the pelagic fry are carried away passively from the spawning places in the warm Atlantic water on the south and west coast, so that when in the course of the summer they reach the age at which it is their nature to seek the bottom in shallow water, they have arrived at the north coast or the east coast.

In this migration of the fry caused by the currents and therefore for the most part passive,

[1] Johs. Schmidt: Contributions to the life-history of the Eel (*Anguilla vulgaris* Turt.), p. 234 et seq. 1906.

which is the first, great migration of the fish, we find the explanation of the appearance of the extremely large quantities of young fish on the north and east coast, in spite of the low temperatures there which are not favourable for the reproduction.

We have further seen that the young during growth remain there throughout the summer and winter. They certainly roam about somewhat in the course of the year, but they are nevertheless able to stand the low winter temperatures of the north and east coasts and thus show themselves very indifferent to the external conditions.

When maturity approaches however, and the fish is preparing for reproduction, it becomes much more sensitive to the external conditions. This results in the undertaking of the second great migration of its life, which having regard for the object may be called the spawning migration, and which ends in the warm water on the south and west coast (see Chart I and figure on p. 10). In contrast to the passive migration of the fry this is a distinctly active movement, induced by definite instincts innate in the fish.

It is therefore the unequal sensitiveness of the fish towards external conditions at different stages of development in conjunction with the purely external conditions (distribution of warm and cold water at the spawning season and the direction of the currents subsequent to this), which determine the distribution of the different stages on the coasts of Iceland. But the interplay between these outer physical and the inner biological factors, which results in the two mutually opposed, great migrations, seems to be marked by the greatest regard for the persistence of the species. By the first, passive migration the developing fry are spread over much greater areas and thus find far better conditions of nourishment than would otherwise have been the case. By the second the older fish, on account of their temporary great sensitiveness to the external conditions, are driven together on relatively small areas, which must naturally be of the greatest importance for the fertilisation of the eggs and through this for the persistence of the species.

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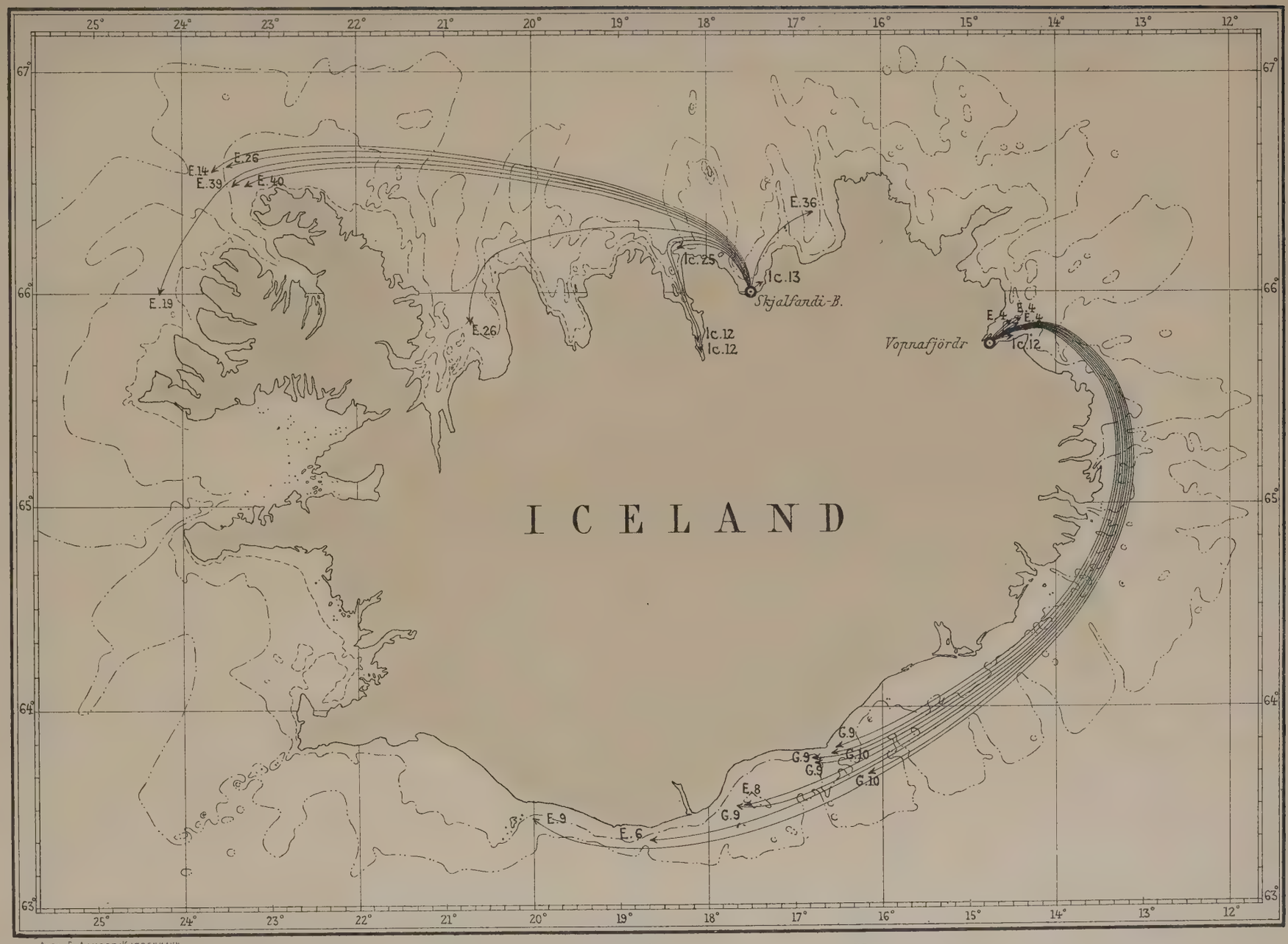

Axel E. Aamodt, Kjøbenhavn

---------- 40 Meter. — . — . — . — 100 Meter. — . . — . . — 200 Meter.

Migrations of Plaice (Pleuronectes platessa). „Thor"s Marking-Experiments in 1903 and 1905.

⊙... *the locality where marked plaice were liberated.*

↗... „ „ *where a marked plaice has been recaptured by British* [E.], *German* [G.] *and Icelandic* [Ic.] *fishermen.*

The number of months between liberation and recovery is indicated by a cipher next to the mark of nationality [E. 9, *etc.*]

Axel E. Aamodt, Kjøbenhavn

---------- 40 Meter. — . — . — . 100 Meter. — .. — .. — 200 Meter.

Migrations of Cod (Gadus callarias). „Thor"s Marking-Experiments in 1904 and 1905.

⊙ ... *the locality where marked cod were liberated.*

↗ ... „ „ *where a marked cod has been recaptured by Icelandic* [Ic.], *Faeroese* [Fo.] *or French* [F.] *fishermen.*

The number of months between liberation and recovery is indicated by a cipher next to the mark of nationality [Fo. 25, *etc.*]

MEDDELELSER FRA KOMMISSIONEN FOR HAVUNDERSØGELSER
SERIE: FISKERI · BIND II · NR. 7 · 1907

ON THE POST-LARVAL DEVELOPMENT OF THE HAKE (*MERLUCCIUS VULGARIS* FLEM.)

BY

JOHS. SCHMIDT

WITH ONE PLATE AND 4 FIGURES IN THE TEXT

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1907

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I. INTRODUCTION

During the Atlantic cruises of the Danish investigation-steamer "Thor" in the years 1903—1906 inclusive, we have gradually obtained the pelagic young of most of the North Atlantic gadoids. On different occasions I have published descriptions of all the species of *Gadus* (including *Gadiculus*)[1] as also of *Brosmius*[2] and the two *Molva*-species, *M. molva* and *M. byrkelange*[3]. On the "Thor"s cruises in the last two years (1905—06), which extended further south than in the earlier years (to Bay of Biscay, Ireland, English Channel), we obtained specimens of the pelagic stages of the young of *Merluccius vulgaris*, *Raniceps raninus*, and of the deep-water ling, hitherto known for the most part only from the Mediterranean, *Molva elongata* Risso, a related species to the northern deep-water ling (*M. byrkelange*). If we except the rockling-genus (*Onos* or *Motella*), which requires a thorough revision even for the adult animals, we now know the pelagic young of all the North Atlantic gadoids which live in shallow water. In the present paper I shall only deal with the post-larval development of the hake (*Merluccius vulgaris*), leaving *Raniceps raninus* and *Molva elongata* till another occasion.

The majority of the stages of the hake described here have been collected by the "Thor". Two small stages of 4—5 mm. in length (Pl. I, figs. 1—2) were found in a collection of gadoid larvæ taken during the Irish fisheries investigations and sent me for determination by Mr. E. W. L. Holt, Dublin, who has kindly permitted me to describe and figure them in this paper.

With regard to the terminology, I may refer to my previous papers (see note below). The following abbreviations have been employed here:

D^1 = 1st Dorsal Fin
D^2 = 2nd do.
A = Anal Fin.

II. DESCRIPTION OF THE DEVELOPMENTAL STAGES

The eggs of the hake were first described by F. Raffaele[4] in his excellent memoir on the pelagic fish eggs and larvæ occurring in the Bay of Naples. According to Raffaele (l. c. p. 37) *Merluccius vulgaris* is ripe there at the end of January. The eggs are 0·94—1·03 mm. in diameter and have an oil-globule

[1] Johs. Schmidt: The pelagic, post-larval stages of the Atlantic species of *Gadus*; Part I. Meddel. Komm. Havunders., Serie Fiskeri, Bind I, No. 4, 1905, Part. II. Ibid. Bind II, No. 2, 1906.

[2] Idem: On the larval and post-larval stages of the Torsk (*Brosmius brosme* [Ascan.]); ibid., Bind I, No. 8, 1905.

[3] Idem: On the pelagic, post-larval stages of the lings (*Molva molva* [Linné] and *Molva byrkelange* [Walb.]); ibid. Bind II, No. 3, 1906.

[4] F. Raffaele: Le uova galleggianti et le larve dei Teleostei nel golfo di Napoli (Mitth. aus der Zool. Stat. zu Neapel, Vol. VIII, 1, 1888, p. 37, Pl. I, Fig. 28, 29, Pl. III, Fig. 1).

(diameter 0·27 mm.). By means of artificial fertilisation on May 3rd, 1886, RAFFAELE was able to determine that the development of the egg took 60—70 hours. The larva on hatching is but little developed. It has an ovoid yolk-sac with the pigmented oil-globule lying posteriorly. As is usual in gadoids the end of the gut does not reach to the margin of the embryonic fin. The early larva has both yellow and black pigment. The later development of the larvæ was not followed by RAFFAELE.

Some young stages of the hake have also been found. Thus, three young specimens were taken by E. W. L. HOLT during the Irish survey. These had a length of $1^1/_4$ to $1^1/_2$ inches (i. e. ca. 32—38 mm.) and were caught in a shrimp-trawl in August at a depth of 80 fms.

As the postlarval stages of the hake have not hitherto been described or figured in literature, the following pages are devoted to the description of the developmental history, which may now be considered as completely elucidated from the available material from the Bay of Biscay, Ireland, Scotland and the Skager Rak. Then follows a verification of the determinations and a summary of the characters by means of which the postlarval stages of the hake can most readily be distinguished from similar or related species.

Pl. I, Fig. 1 **Length: $4^1/_4$ mm.** At this stage the form of the larva has no very special characteristics. The preanal portion is however comparatively thick, the notochord quite straight. Embryonic rays are present in the embryonic fin but there is not trace of true rays or interspinous rays. The pectorals are ray-less flaps and the ventrals have not yet appeared.

The pigment offers several characteristics which make the fish, in spite of its small size, easily recognizable from nearly related species. It is as usual the postanal pigment especially which is important for diagnostic purposes. With regard to the terminology used in the description of the pigment, see my earlier papers (p. 3, foot-note) on the developmental history of other gadoids. There are some large chromatophores on the neck and pectoral region. The abdominal pigment is conspicuous, and the ventral preanal pigment is also rather distinct.

As mentioned, the postanal pigment is specially characteristic, consisting as in so many other gadoids of 3 separate bars (I, II, III), the posterior (I) lying a little in front of the end of the notochord, the anterior (III) some distance behind the anus. Bar I consists of a large mediolateral chromatophore or also of several small. In any case the pigment bar I is quite restricted to the tail without extending out on to the fin (i. e. embryonic fin) as in several other gadoids (e. g. *Brosmius* and *Molva*, cfr. text-figure, p. 9). The ventral part of I is stronger than the dorsal. Bar III which as mentioned is some distance behind the anus, consists essentially only of a single large, stellate, mediolateral chromatophore. Bar II lies between I and III but nearer III than I. This bar is also mediolateral generally but may be somewhat prolonged dorsally. Sometimes also, it may consist of a dorsal and a ventral portion as well as the mediolateral, so that it almost surrounds the body like a ring. In general the dorsal part is more developed than the ventral. In this and the following stages II is the strongest and most distinct of the 3 postanal pigment bars.

Pl. I, Fig. 2 **Length: 5 mm.** The form is as in the previous stage or even a little thicker anteriorly. The end of the notochord is quite straight, and there is no sign of rays or interspinous rays in the fins. In the caudal region, however, under the posterior part of pigment bar I there is a slightly more opaque spot in the embryonic fin close up to the body contour. The pectorals also have no trace of rays or basal elements. The pigment is essentially as before.

Pl. I, Fig. 3 **Length: 6 mm.** The trunk is somewhat thicker than before. The notochord is quite straight. The first traces of interspinous rays are now seen both above and below in the caudal fin as an opaque part in the embryonic fin, though less in extent above. Otherwise all traces of interspinous rays and rays

are quite lacking in the unpaired fins and pectorals. The ventrals have now made their appearance as characteristic conical knobs with very black pigment, which are as yet scarcely so long as the diameter of the eye but still sufficiently long to show that the hake belongs to the group of gadoids having elongated ventral fins at an early stage of development. The pigment is essentially as before. In the specimen figured each of the three postanal bars consists mainly only of one large mediolateral, stellate chromatophore.

Length: 8 mm. The anterior part of the body is thick, just as is the case in certain other gadoids in the early postlarval stages (e. g. *Gadus œglefinus* and *Gadiculus argenteus*). The notochord is still straight. In the caudal fin the hypural elements are distinct both above and below, but the rays are as yet not distinctly defined. In D^2 and A the interspinous region can be traced from the beginning of the fins backwards to a little behind pigment-bar II, but the rays are not yet formed. D^1 has already begun to separate off from the embryonic fin. It has some few (ca. 5) incipient rays which, however, are not yet distinctly formed. The anus lies a good distance behind the interspace between D^1 and D^2. The ventrals are now distinctly longer than the diameter of the eye. They are strongly pigmented and reach posteriorly scarcely to the anus. The pigment is in the main unchanged. Pl. I, Fig. 4

Length: 8 3/4 mm. In spite of the slight difference in length between this and the previous stage the fish has increased in volume very considerably. It is very thick. Taken on the whole the specimen is much further on in development than the foregoing. The notochord is no longer quite straight. Rays are now present in a great part of the caudal fin, but there is still a somewhat considerable, ray-less part posteriorly. Rays are now beginning to appear in the second dorsal and anal fins with the exception of the posterior part in both. They are still short and thus do not extend out to the margin of the embryonic fin. In each of these fins ca. 27—28 rays could be counted. The embryonic fin is still broad between the caudal fin and the other unpaired fins. D^1 is not yet separated from D^2; it has 7—8 distinct rays which are longer than those in D^2. There is no pigment whatever on the unpaired fins. The ventrals which are covered with very black pigment reach backwards to the anus. As their rays are enclosed in a common skin they are very broad, almost like flippers. The pigment on the body is unchanged. Pl. I, Fig. 5

Length: 9 1/2 mm. The form is plump; the end of the notochord is now somewhat bent and reduced in thickness. In the caudal fin there is now only a small ray-less part above posteriorly. The rays in D^2 and A mostly extend out to the margin of the embryonic fin, which is still broad between the caudal fin and the other unpaired fins. D^1 is not yet separated from D^2, but is higher than the latter. One characteristic is that D^1 has some black pigment spots; otherwise there is no pigment on the unpaired fins. 7 rays could be counted in the ventral fins. The pigment on the body is essentially unchanged. The sides of the abdomen are strongly pigmented. Pl. I, Fig. 6

Length: 10 1/4 mm. The form of the body is still very plump. The end of the notochord is much bent and considerably reduced. Most of the rays are now present in D^2 and A; some few only are still lacking posteriorly. The embryonic fin between the caudal fin and D^2 and A is now lower than in the previous stage, but there is still no separation. D^1 is higher than before and has already several dashes of black pigment anteriorly. The ventrals reach to behind the anus and are strongly pigmented with black. The pigment on the body is distinct. Some pigment (anterodorsal) has appeared under D^1. The postanal pigment is essentially unchanged. Pl. I, Fig. 7

Length: 12 1/4 mm. The body is still very plump. Rays are present everywhere in the caudal fin and the hind margin of the posterior hypural element is now vertical and bears 6 rays. The embryonic Pl I, Fig. 8

fin between the caudal fin and the other unpaired fins is very low and rays are present everywhere in D^2 and A (ca. 35 rays could be counted in each). In D^1 which is high and distinctly pigmented the rays are more clearly marked and further on in development than in D^2 and A. The ventrals are as before; posteriorly they reach a little behind the anus. The pigment on the body is essentially unchanged. The ventral part of bar I is as a rule stronger than the dorsal and II may often be dorsolateral. On the other hand I is usually mediolateral. II is the most distinct of the three postanal bars.

Pl. I, Fig. 9 **Length: 15 mm.** No little change in the body has occurred since the preceding stage. The form is considerably more slender than in the specimens previously described, and is thus a transition to the older developmental stages which are remarkable just for their slenderness. The end of the notochord is much reduced and bent upwards. The caudal fin is of elongated form with a convex posterior margin. The embryonic fin is still present between the caudal fin and D^2 and A, but is low. In A and D^2 ca. 35 rays could be counted, the most posterior of which are very indistinct. D^1 which as before is strongly pigmented with black is separated from D^2 and contains ca. 9 rays. The pectorals are still rounded, fan-like and have traces of rays. The ventrals are dark-coloured and reach backwards to a little behind the anus. They contain 7 rays, the outermost of which is shortest and the fourth longest. The fins lack pigment with exception of D^1 and the ventrals. The postanal pigment is not essentially altered in this specimen, though this may occur in other specimens of the same size. The changes that occur in the 3 postanal bars during the development of the pigment will be mentioned in describing the following stage.

The pigment mentioned earlier as occurring dorsally beneath D^1, has increased in extent and now forms quite a large patch. Looking at the fish from above we notice that there is a lighter, unpigmented part in the centre of this large, dorsal pigment patch, so that this is almost in the shape of a ring.

Further, a small group of pigment has been added under the anterior part of D^2, but this is situated lower down on the side (dorsolateral) than the large patch under D^1.

Pl. I, Fig. 10 and 10 a **Length: 16½ mm.** As development advances the form of the body becomes gradually more and more slender and approaches nearer to that of the adult. The anus lies almost under the interspace between D^1 and D^2. The caudal fin which is elongated and has a convex posterior margin, is now separated from A and D^3, the embryonic fin having disappeared. In D^1 there were 8, in D^2 ca. 37 and in A ca. 37 rays. The ventrals reach posteriorly to a little behind the anus. They are black pigmented which is also the case with D^1, whereas there is no pigment on the other fins.

The postanal pigment is now obviously altered and in a characteristic way, new elements having appeared. The three primary bars or groups are still present and are a little more pronounced than the remaining postanal pigment. The latter consists chiefly of two groups IIa and IIIa which have appeared behind bars II and III respectively. They are not situated medio-laterally like II and III but dorsally, as can be seen both from Fig. 10 and Fig. 10 a which represents the fish viewed from above. These two postanal, secondary groups IIa and IIIa are very characteristic of the older postlarval stages of the hake. Some few chromatophores in a row have also appeared mediolaterally in front of and behind bar III. The dorsolateral group mentioned under the previous stage as occurring below the beginning of D^2 is still fairly well marked (cf. Fig. 10 a), as is also the large dorsal patch under D^1.

Pl. I, Fig. 11 **Length: 19 mm.** This specimen does not show any great changes. We notice, however, that the body is steadily becoming more slender. The anus is placed almost under the interspace between D^1 and D^2. The pigmentation is on the whole as in the stages previously described. The pigment groups appearing in the stages of this size give the fish a characteristic, marbled appearance, but there may be great individual variation in the strength and degree of development of the pigment.

Length: 26 mm. The body is slender and the head has already the flat form which is characteristic of the hake. The anus is almost under the interspace between D^1 and D^2. The caudal fin is long and narrow and its posterior margin is convex. It contains 40 rays. D^1 has ca. 9, D^2 ca. 36 and A 37 rays. Both D^2 and A are slightly concave. The pectorals are still broad, fan-shaped and relatively far back in development, the lower part having only embryonic rays. The ventral fins, which reach some distance behind the anus, contain 7 rays. They are more weakly pigmented than in the earlier postlarval stages. The pigmentation on the body has not essentially changed. Some dorsal pigment has been added, extending from the postoccipital region backwards along the base of D^2. Pl. I, Fig. 12

Length: 31 mm. The body is slender and the head flat just as in older specimens. In the caudal fin there are 40 rays, but the numbers could not be determined in the other unpaired fins as these were contracted and pressed together. The pectorals are considerably narrower and further forward in development than in the preceding stage. The ventrals which reach some distance behind the anus are now only somewhat faintly pigmented. Of the unpaired fins only D^1 is pigmented, D^2, A and the caudal fin lacking pigment. Pl. I, Fig. 13

With regard to the pigment, the three original bars (I, II, III) and also the two secondary ones (II a and III a) can still be recognised, but as so much pigment has been added they are no longer so prominent as they were before. A broad dorsal streak of pigment is now present, extending from the postoccipital region backwards to the caudal fin. It is broadest in front and consists of numerous, densely placed chromatophores. Further, the postanal pigment has been increased by some ventral or ventrolateral groups posteriorly (behind bar I) and by some few, large stellate chromatophores arranged mediolaterally in a row behind and in front of bar III. Altogether this arrangement of pigment gives the characteristic, marbled appearance already mentioned, which is so unusual in the young of gadoids but reminds one somewhat of what occurs, for example, in young gobies, various young cottoids etc.

The body in front of the anus is likewise densely pigmented; thus the abdominal pigment is very pronounced.

To describe and figure older stages seems superfluous as they so much resemble the adult fish in form, position of the fins etc., that their determination should be an easy matter.

III. VERIFICATION OF THE DETERMINATIONS

In the ichthyological text-books of Krøyer[1], Day[2], Lilljeborg[3], Smitt[4] and Moreau[5] we find the following numbers given for the vertebræ and fin-rays in *Merluccius vulgaris*.

	Vertebræ, total no.	Vertebræ without hæmal arches	Vertebræ with arches	Rays in D^1	Rays in D^2	Rays in A	Rays in ventral
Krøyer	.....	.....	.....	9—10	39—40	39—40	7
Day	51	25	26	10	36—40	36—38	7
Lilljeborg	50—52	24—25	.....	10—11	37—40	37—40	7
Smitt	50—52	.....	.....	9—11	37—39	37—39	7
Moreau	.....	.....	.....	10	36—40	36—38	7

[1] H. Krøyer: Danmarks Fiske, 3 vol., Kjøbenhavn, 1838—53.
[2] F. Day: The Fishes of Great Britain and Ireland, 2 vol., London, 1880—84.
[3] W. Lilljeborg: Sveriges och Norges Fiskar, 3 vol., Upsala, 1891.
[4] F. A. Smitt: Skandinaviens Fiskar, 3 vol., Stockholm, 1892.
[5] E. Moreau: Poissons de la France, 3 vol., Paris, 1881.

The foregoing description shows that the number of fin-rays in these post-larval gadoids agrees well with what is given in the table for *Merluccius*.

Further, I have determined the number of vertebræ in a number of postlarval stages of 10—20 mm. in length. The specimens came from Scotland, the Skager Rak and the north coast of Spain, and the vertebræ were counted after the larvæ had been dehydrated in alcohol and cleared in xylol. The following table gives the numbers (the first indicate the vertebræ without, the second the vertebræ with hæmal arches).

Scotland	$^{24}/_{26}$	$^{24}/_{27}$	$^{25}/_{25}$	$^{25}/_{26}$	$^{25}/_{27}$
Skager Rak	$^{25}/_{26}$	$^{25}/_{26}$	$^{25}/_{26}$	$^{25}/_{27}$	$^{26}/_{26}$
North coast of Spain	$^{24}/_{26}$	$^{25}/_{26}$	$^{25}/_{26}$	$^{25}/_{26}$	$^{25}/_{27}$	$^{25}/_{27}$

We see from this that the number of vertebræ in these postlarval gadoids, which were characterized in external appearance by the three postanal pigment-bars, agrees exactly with the number of vertebræ in the hake and it is worth noting as a special characteristic, that there are almost as many vertebræ in the trunk as in the tail. Generally, the rule amongst gadoids is that there are considerably more caudal vertebræ than abdominal. There can therefore be not the slightest doubt that the series described really belongs to the developmental stages of the hake, especially as we have now gradually learnt to distinguish the postlarval stages of almost all the gadoids living in shallow water in the Northern Atlantic.

IV. DISTINCTION BETWEEN THE HAKE AND ALLIED SPECIES IN THE POSTLARVAL STAGES

On the basis of our present knowledge we may group together — for the sake of a summary — the North Atlantic gadoid genera occurring in shallow water in the following manner, according to the appearance of the earlier postlarval stages.

I. Ventral fins not prolonged ..... *Gadus* (with *Gadiculus*).

II. Ventral fins prolonged.

(1). Pigment behind the anus typically arranged in 3 bars (I, II, III), the most posterior (I) lying near the end of the tail[2].

(a). Ventrals much prolonged, reaching far past the anus,

α. Ventral rays free nearly throughout their entire length, swollen at their tips ..... *Brosmius*.

β. Ventral rays united by a membrane, thin at their tips ..... *Molva*.

(b). Ventrals not very much prolonged, not reaching far beyond the anus *Merluccius*.

(2). Pigment behind the anus not arranged in 3 bars (I, II, III), the most posterior (I) lying near the end of the tail.

(a). No postanal pigment-bars present ..... *Raniceps*.

(b). 1 postanal pigment-bar present ..... *Onos*[3].

[1] Of the species whose postlarval history is not well known, *Phycis blennioides* has $^{15}/_{35}$ vertebræ, *Raniceps raninus* $^{11}/_{33-34}$, *Onos cimbrius* $^{16—17}/_{36—41}$ (according to LILLJEBORG, l. c.).

[2] In *Molva molva* the most posterior of the 3 postanal bars is wanting but the two others are present and have the typical position.

[3] As far as the species are hitherto known.

As the hake has prolonged ventral fins there can be no question of confusing its postlarval developmental stages with any of the species under the genera *Gadus* or *Gadiculus*.

Merluccius is readily distinguished from *Molva molva* even in the earliest stages by the presence of pigment-bar No. I.

From *Molva byrkelange, Molva elongata* and *Brosmius brosme*, in which bar I is present, *Merluccius* is distinguished by the fact that bar I is restricted to the tail itself without as in these extending on to the caudal fin (see figures in text), and it further differs in the very plump form of the trunk, especially in the earlier postlarval stages, and lastly in that the ventral fins are by no means so prolonged as in the genera *Molva* and *Brosmius*.

Merluccius is distinguishable from *Onos* firstly by having three postanal pigment-bars, secondly by the older postlarval stages lacking the silvery sheen which characterizes the *Onos*-genus (also *Phycis* according to LÜTKEN, FACCIOLA a. o.); and lastly, it is distinguished from *Raniceps*, which in its early postlarval stages reminds one mostly of the species of the *Liparis*-genus, by having the three postanal bars mentioned whereas these are absent in *Raniceps*.

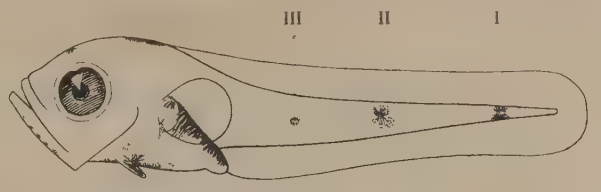

Fig. 1. *Merluccius vulgaris* (Length: 6 mm.)
(Note that the most posterior bar (I) is quite restricted to the tail without extending on to the caudal fin (cf. figs. 3, 4).

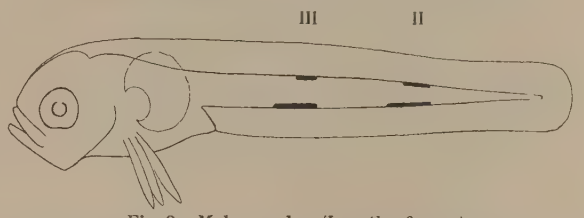

Fig. 2. *Molva molva* (Length: 6 mm.)
Semidiagrammatic figure, in which the preanal pigment is not shown.
(Note the absent of the posterior pigment bar I)

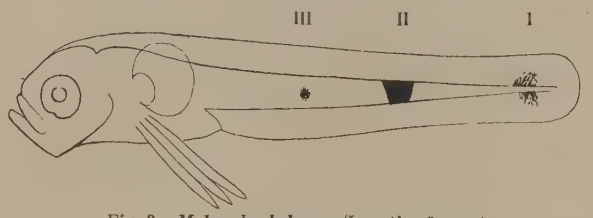

Fig. 3. *Molva byrkelange* (Length: 6 mm.)
Semidiagrammatic figure, in which the preanal pigment is not shown.
(Note that bar II is most developed dorsally and that there is no pigment at the end of the notochord.)

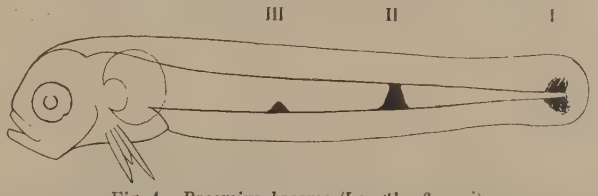

Fig. 4. *Brosmius brosme* (Length: 6 mm.)
Semidiagrammatic figure, in which the preanal pigment is not shown.
(Note the short preanal part, that bar II is most developed ventrally and that pigment is present right to the end of the notochord.)

For the rest, we may take as important, general, diagnostic characters of *Merluccius* the plump form of the trunk in the earlier, postlarval stages, specially prominent at sizes between ca. 7 and ca. 15 mm., and in the older stages the pigmentation, which gives the fish a marbled appearance similar to that in the young of certain *Gobius*-species and various cottoids (e. g. *Triglops*) but which seems to be very uncommon in the gadoid group. In the earlier postlarval stages it is as mentioned the position of the 3 postanal pigment-bars which is so very characteristic (I, only on the tail itself and not on the caudal fin and which as a rule is most developed ventrally; II, either mediolateral or dorsolateral; and III, as a rule mediolateral).

With the exception of the ventrals and the anterior part of D^1 the fins lack pigment even in the older postlarval stages.

EXPLANATION OF PLATE

Merluccius vulgaris Flem.

Fig. 1. Length: 4 1/4 mm. Irish investigation-steamer "Helga", Stat. S.R. 265, 2nd November 1905. 51° 16′ N, 8° 10′ W (Ireland). Depth: 54 fathoms. Depth of apparatus: 25 fathoms.

Fig. 2. Length: 5 mm. Same haul as Fig. 1.

Fig. 3. Length: 6 mm. "Thor", Stat. 34, 8th May 1906. 47° 55′ N, 4° 52′ W (Bay of Biscay). Depth: 50 meters. Young-fish trawl, 60 meters wire out.

Fig. 4. Length: 8 mm. "Thor", Stat. 32, 7th May 1906. 48° 40′ N, 5° 04′ W (Mouth of the English Channel). Depth: 113 meters. Young-fish trawl, 50 meters wire out.

Fig. 5. Length: 8 3/4 mm. "Thor", Stat. 289, 5th September 1904, 58° 44′ N, 3° 21′ W (N. of Scotland), Depth: 95 meters. Young-fish trawl, 20 meters wire out.

Fig. 6. Length: 9 1/2 mm. "Thor", Stat. 39, 11th May 1906, 43° 39′ N, 2° 07′ W (Bay of Biscay), Depth: 1420 meters. Young-fish trawl, 300 meters wire out.

Fig. 7. Length: 10 1/4 mm. "Thor", Stat. 168, 2nd September 1905. 58° 42′ N, 6° 13′ W (N. of Scotland), Depth: 110 meters. Young-fish trawl 65 meters wire out.

Fig. 8. Length: 12 1/4 mm. "Thor", Stat. 39, 11th May 1906, 43° 39′ N, 2° 07′ W (Bay of Biscay), Depth: 1420 meters. Young-fish trawl, 300 meters wire out.

Fig. 9. Length: 15 mm. "Thor", Stat. 39, 11th May 1906, 43° 39′ N, 2° 07′ W (Bay of Biscay), Depth: 1420 meters. Young-fish trawl, 300 meters wire out.

Fig. 10. Length: 16 1/2 mm. "Thor", Stat. 41, 14th May 1906, 43° 23′ N, 2° 01′ W (N. coast of Spain), Depth: 102 meters. Young-fish trawl, 120 meters wire out.

Fig. 10 a. The same specimen seen from the dorsal aspect.

Fig. 11. Length: 19 mm. "Thor", Stat. 41, 14th May 1906, same trawl as Fig. 10.

Fig. 12. Length: 26 mm. "Thor", Stat. 35, 8th May 1906, 47° 05′ N, 4° 26′ W (Bay of Biscay), Depth: 146 meters. Young-fish trawl, 175 meters wire out.

Fig. 13. Length: 31 mm. "Thor", Stat. 41, 14th May 1906, 43° 23′ N, 2° 01′ W (N. coast of Spain), Depth: 102 meters, Young-fish trawl, 60 meters wire out.

Note. In the older postlarval stages the outlines of D^2 and A are slightly concave. By the reproduction of the figures they have wrongly been made almost straight.

Misprints

Nr. 6, p. 12, line 10 from beneath and p. 21, line 2 from beneath; instead of: shore, read: share.

550. 30/v 1907

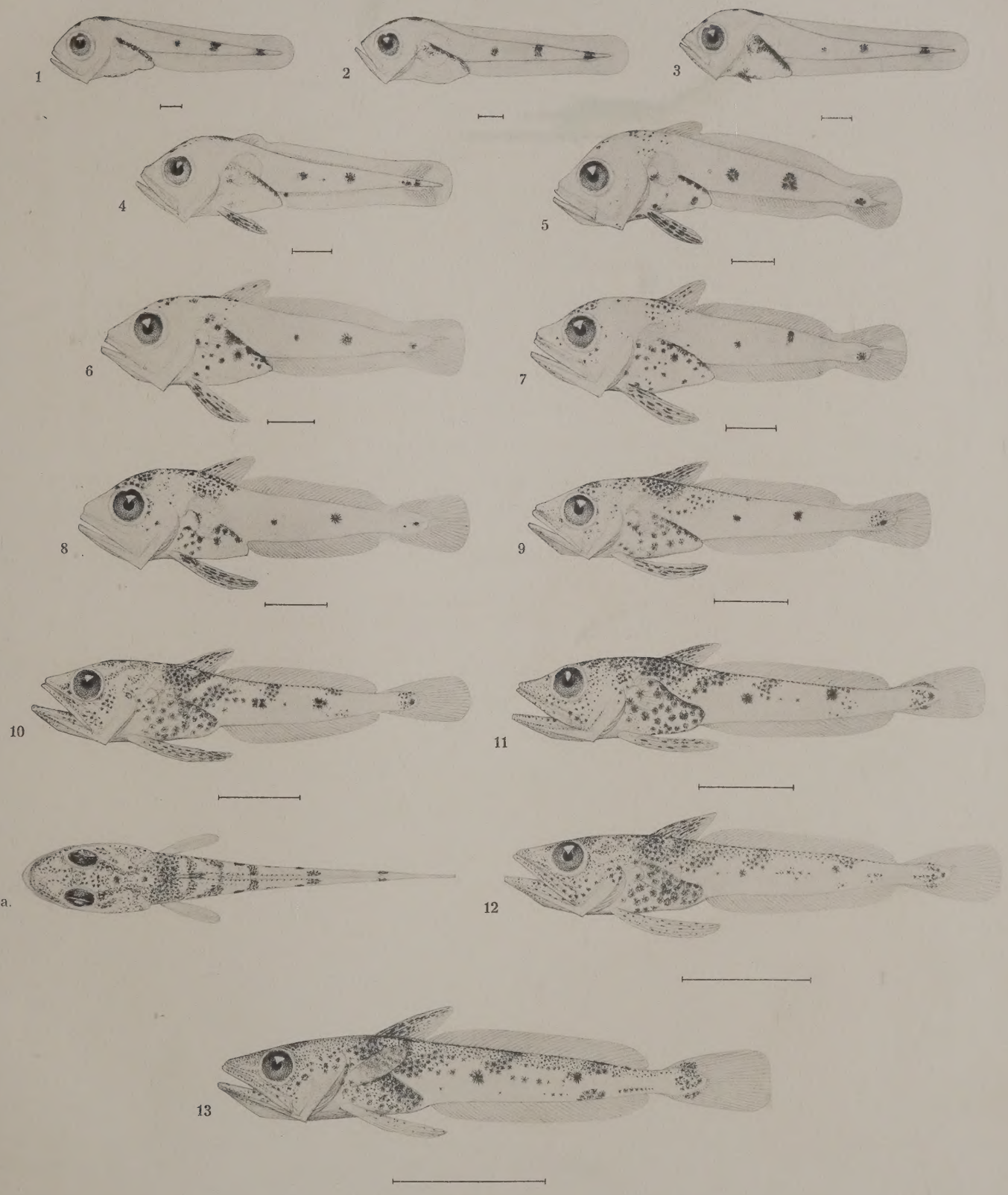

Fig. 1—13 *Merluccius vulgaris* Flem.